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UPLINK SCRAMBLING CODE ASSIGNMENT FOR A RANDOM ACCESS CHANNEL

This application claims priority from U.S. Provisional Application No. 60/134,880, filed May 19, 1999.

BACKGROUND

The invention relates generally to resource allocation in a wireless code division multiple access (CDMA) communication system. More specifically, the invention relates to assigning uplink scrambling codes in a CDMA communication system.

Figure 1 depicts a wireless spread spectrum Code Division Multiple Access (CDMA) communication system **20**. A base station **22** communicates with user equipment (UE) $\mathbf{24_1}$-$\mathbf{24_n}$ in its operating area. In a spread spectrum CDMA system **20**, data signals are communicated between UEs $\mathbf{24_1}$-$\mathbf{24_n}$ and the base station **22** over the same spectrum. Each data signal in the shared spectrum is spread with a unique chip code sequence. Upon reception, using a replica of the original chip code sequence, a particular data signal is recovered.

Since signals are distinguished by their chip code sequences (code), separate dedicated communication channels are created using different codes. Signals from the base station **22** to the UEs $\mathbf{24_1}$-$\mathbf{24_n}$ are sent on downlink channels and signals from the UEs $\mathbf{24_1}$-$\mathbf{24_n}$ to the base station **22** are sent on uplink channels. For coherent detection of downlink

transmissions by the UEs **24_1-24_n**, pilot signals are transmitted to all of the UEs **24_1-24_n** within the base station's operating range. The UEs **24_1-24_n** condition their receivers based on the pilot signals to enable data reception.

In many CDMA systems, a random access channel, such as the common packet channel (CPCH), is used for some uplink transmissions. A CPCH is capable of carrying packets of data from different UEs **24_1-24_n**. Each packet is distinguishable by its code. For detection by the base station **22**, the packets have a preamble which also distinguishes it from other packets. The CPCH is typically used to carry infrequently communicated data at high rates.

Figure 2 illustrates a CPCH time slot and frame structure. The CPCH structure is time divided into radio frames **30_1-30_m** having time slots **28_1-28_n**, such as eight time slots proposed for the Third Generation Mobile Telecommunications System (IMT-2000)-UMTS. A radio frame **30_1-30_m** in IMT-2000 is 10 milliseconds in duration and each time slot is 1.25 ms. The radio frames **30_1-30_m** are grouped into superframes **32**. Each superframe **32** has a fixed number of radio frames **30_1-30_m**, such as 72 radio frames in IMT-2000.

To allow more than one UE **24_1-24_n** to use a given time slot **28_1-28_n**, multiple signatures are used to distinguish the UEs **24_1-24_n**. In IMT-2000, sixteen different signatures are used. A particular signature used within a particular time slot is referred to as an access opportunity. **Figure 3** illustrates the access opportunities **26_{11}-26_{mn}** of the CPCH. For instance, as proposed for IMT-2000, for each of the 8 time slots, one out of 16

signatures is available to be chosen, resulting in 128 access opportunities. Each access opportunity 26_{11}-26_{mn} is preassigned an uplink scrambling code. The scrambling code is a function of the time slot T_K and the signature S_K that the UE used for access. Accordingly, the uplink scrambling code, C_K, is a function of the time slot, T_K, and signature, S_K, of the access opportunity 26_{11}-26_{mn} as in **Equation 1**.

$$C_K = 8 * T_K + S_K \qquad \textbf{Equation 1}$$

The UE $\mathbf{24_1}$ transmits a data packet using a selected access opportunity 26_{11}-26_{mn}. Upon identifying a particular access opportunity 26_{11}-26_{mn}, the base station **20** sends out an acknowledgment message (ACK) if the corresponding scrambling code is available. The ACK message may be one of several types, such as simply being a downlink transmission of the signature associated with the UE's access attempt. If the scrambling code is not available, a negative acknowledgment (NAK) is sent. After receiving the appropriate ACK message, the UE $\mathbf{24_1}$ selects the proper uplink scrambling code to transmit the packet data on the CPCH. If the UE $\mathbf{24_1}$ receives a NAK, it will re-attempt access by transmitting another packet.

This approach for assigning uplink scrambling codes has drawbacks. A typical scrambling code is only 10 ms in length. A transmitted data packet may last more than one radio frame **30**. Since a data packet may last for multiple radio frames, the scrambling code used for that packet can only be reassigned after the transmission of that packet is complete.

As a result, the number of CPCH users is limited by the number of scrambling codes assigned to the access opportunities $\mathbf{26_{11}}$-$\mathbf{26_{mn}}$, such as 128 scrambling codes. Additionally, if a second user uses the same access opportunity $\mathbf{26_{11}}$-$\mathbf{26_{mn}}$ as an already transmitting first user, the second user will receive a NAK. Repeated negative access attempts lower the efficiency of the system **20** which is undesirable.

Accordingly, it is desirable to use alternate scrambling code assignment schemes.

SUMMARY

A user equipment transmits a data packet using a selected signature in a time slot of a radio frame within a superframe of a common packet channel. The superframe being time divided into radio frames. A base station identifies the selected signature, transmission time slot and transmission radio frame of the data packet. The base station determines an uplink scrambling code for the user equipment based on in part the identified signature, transmission time slot and transmission radio frame. The base station selectively transmits an acknowledgment message based on in part an availability of the determined uplink scrambling code. The user equipment receives the acknowledgment message and transmits a subsequent data packet using the determined uplink scrambling code.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an illustration of a typical wireless spread spectrum CDMA

communication system.

Figure 2 is an illustration of the time slots, radio frames and superframes of the random access channel.

Figure 3 is an illustration of a random access channel access scheme.

Figure 4 is a flow chart of uplink scrambling code assignment.

Figure 5 is a simplified base station and user equipment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 4 is a flow chart of uplink scrambling code assignment. To initiate communications with the base station **22**, a UE $\mathbf{24_1}$ transmits a data packet over the random access channel, such as a CPCH. The packet is transmitted with a selected access opportunity $\mathbf{26_{11}\text{-}26_{mn}}$. The selected access opportunity $\mathbf{26_{11}\text{-}26_{mn}}$ is defined by its signature and time slot in a radio frame $\mathbf{30_1\text{-}30_m}$. The UE $\mathbf{24_1}$ also knows which radio frame $\mathbf{30_1\text{-}30_m}$ within the superframe and access opportunity $\mathbf{26_{11}\text{-}26_{mn}}$ the packet was transmitted, **34**. For instance, in a system $\mathbf{30_1\text{-}30_m}$ having a superframe **32** of seventy-two radio frames $\mathbf{30_1\text{-}30_m}$, an access opportunity $\mathbf{26_{11}\text{-}26_{mn}}$ using code 2 in time slot 4 sent in the twentieth radio frame in the superframe sequence is known by the UE $\mathbf{24_1}$.

The base station **22** identifies the access opportunity $\mathbf{26_{11}\text{-}26_{mn}}$ and the radio frame **30** within the superframe **22** in which the packet was transmitted, **36**. The uplink scrambling codes are assigned based on a function of the selected access opportunity $\mathbf{26_{11}\text{-}26_{mn}}$ and

radio frame 30_1-30_m used by the UE 24_1 for the packet as in **Equation 2, 38.**

$$C_K = g\,(F_K, T_K, S_K) \qquad \textbf{Equation 2}$$

F_K is the transmitted packet's radio frame 30_1-30_m within the superframe **32**. Using **Equation 2**, the number of uplink scrambling codes that may be assigned is dramatically increased. For a system using eight time slots, sixteen signatures and seventy-two radio frames within the superframe **32**, the possible uplink scrambling code assignments increases from a maximum of 128 to 9,216. By increasing the available scrambling codes, the number of users capable of utilizing the CPCH is increased. Although increasing the number of available scrambling codes is desirable, it has drawbacks. The codes available to the system **20** is a limited resource and should be allocated conservatively.

One approach to limit the available scrambling codes with no or a negligible decrease in the number of users is to reassign codes after a number of radio frames 30_1-30_m. Some packets may last more than a single radio frame. However, the packet length typically does not exceed a certain number of radio frames 30_1-30_m. Additionally, based on the system **20**, the packet length may also be limited as a system parameter. A typical limitation for an IMT-2000 system would be eight radio frames. Since the packet duration is limited or the duration typically does not exceed a limit, the uplink scrambling codes may be repeated after a specified number of radio frames, the limit, L. The limit, L, may be a system design parameter. The limit, L, may also be broadcast or transmitted to the UEs 24_1-24_n at call setup or on a periodic basis.

For a system using a radio frame limit of L, **Equation 3** is a function for such an uplink scrambling code assignment.

$$C_K = g\left((F_K)_L, T_K, S_K\right) \qquad \textbf{Equation 3}$$

$(.)_L$ denotes a modulus-L operation. As a result, the uplink scrambling code assignments are repeated every L radio frames. Since no packets or a negligible number of packets exceed the frame limit, L, the number of users using the CPCH is not reduced.

For a system using an eight radio frame limit (L = 8), **Equation 3** becomes **Equation 4**.

$$C_K = g\left((F_K)_8, T_K, S_K\right) \qquad \textbf{Equation 4}$$

Using **Equation 4** in a 16 signature, 8 time slot system, the maximum number of assignable uplink scrambling codes is reduced to 1,024. Using **Equations 3** or **4** and the limit, L, the number of necessary uplink scrambling codes is kept to a low level with the number of potential users being increased dramatically.

Using either **Equation 3** or **4**, the base station **22** determines whether the scrambling code associated with the UE's access attempt is available, **40**. If that uplink scrambling code is not available, a NAK message is sent to the UE $\mathbf{24_1}$, **42**. After receiving a NAK message, the UE $\mathbf{24_1}$ will reattempt access, **44**.

If the determined uplink scrambling code is available, the base station **22** transmits

an ACK message to the UE **24_1**, **46**. Subsequently, the UE **24_1** will transmit packet data using the uplink scrambling code associated with the UE's access attempt.

Figure 5 illustrates a simplified base station **22** and a UE **24_1** for use in implementing uplink scrambling code assignment. The UE **24_1** has a controller **60** for determining the scrambling code of the uplink data packets. A UE transmitter **58** sends uplink data packets to the base station **22** based on the determined scrambling code. A UE receiver **56** receives communications from the base station **22**.

The base station **22** has a controller **50** for determining the scrambling code of the uplink data packets. A base station transmitter **52** sends communications to the UE **24_1**. The base station receiver **54** receives uplink data packets from the UE **24_1** using the determined scrambling code.

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